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Performance Evaluation of Rake and Pre-Rake Receiver for a Wireless DS-CDMA System

Manish Rai, Amanpreet Singh Saini
Department of Electronics & Communication Engineering
Galgotias College of Engineering & Technology,Greater Noida(UP)-India

ABSTRACT

A new method to deal with multi path fading environment for DS–CDMA wireless networks has been proposed. Here, depending upon the statistical nature of the channel, signal is transmitted as a sum of various spreaded signals; each one delayed and scaled according to the delay & strengths of the multi paths of the transmitted channel. New method known as Pre-Raking is performed at the transmitted side rather than the conventional rake method performed at receiver side taking considerations of BPSK modulation scheme. This makes an easier design to the portable mobile sets. Simulated analyses for both the processes have been done for orthogonal and random codes using Monte-Carlo method. Results show that both methods give nearly equal performance for orthogonal codes whereas Pre-raking over-performed raking for random codes.

Keywords: *Rake Receiver, Pre-Rake Receiver, DS-CDMA, BPSK Modulation*

1. MULTIPATH FADING CHANNEL

In mobile radio communication environment, transmitted signal might undergo several reflections and local scatterings depending upon various multi paths available in the channel reaching at the receiver. These scattered signals are subjected to random delay, fluctuations and phase shifts. Multi paths are received through various diversity schemes including raking.

2. RAKE RECEIVER

Here, multi paths may be appreciated as linear combinations of different delayed echoes. Rake combiner makes use of transversal filter or an equivalent device & channel estimator. As both of these devices are computationally complex to implement and power consuming, these techniques are undesirable for the hand held mobile units [1].

In cellular mobile communications, it is desirable to keep the complexity and hence size & cost of the mobile unit to a minimum and concentrate all the complexities at the base station. A single path receiver is the most desirable receiver in such a situation. Hence, a new diversity method known as Pre-rake diversity combining scheme is used at transmitted side.

3. PRE-RAKE COMBINING SYSTEM

The rake signal can be viewed as the sum of the multipath signals with received signal from each path being scaled by a factor related to the strength of that path. The operation is an equivalent operation to the multiplication of the received signal by the time reversed channel impulse response. However in pre-raking, the future channels impulse response i.e. the strength and the corresponding relative phases of the multipaths is estimated and the above mentioned multiplications are carried out at the transmitter side. The received signal will then be equivalent to the rake-combined signal since the same linear operation can be performed for both the systems, although in different order.

The channel impulse response consists of a series of impulses. The amplitude and phase of each impulse represents the specifics of the single path. The time delay associated with the impulse is determined from the propagation delay of that path. The output signal in the pre-rake combiner is the result of the convolution of the direct spreading CDMA signal and the time reverse channel impulse response.

The receiver in the Pre-Rake combiner will be a single path receiver, which decodes only the $(L-1)^{th}$ peak of the matched filtering each received symbol, if L is total multi paths available in the channel. The combiner parameters here will be future path strengths, path delays and path phase and must be estimated.

4. MATHEMATICAL MODEL FOR PRE-RAKE SYSTEM

Assumptions made for the system are as follows:

1. Channel is estimated by simplified tapped-delay line model.
2. Uplink channels are assumed to be statistically independent for all users.
3. With the utilization of up-link power control, it is assumed that all the channels are statistically identical even if mobile units

are at different distances from the base station at the transmitter side. Complex low pass impulse response of the channel of the user (k) is specified as[2,3]

$$\sum_{l=0}^{L}\beta_{k,l}.\exp(j.\gamma_{k,l}).\delta(t-lT_c)$$

Where L is the number of Channel paths, $\beta_{k,l,}$ is the different Path Gains, $\gamma_{k,l}$ is the different Phase Angles and T_c is the PN Sequence code-chip duration. Now, assuming system with K number of users, the received signal at user number 1 during the downlink time slot is given by

$$R_i(t)=n(t)+R_e\left\{\sum_{k=1}^{K}\sum_{j=0}^{L-1}\beta_{i,j}.S_k(t-T_c).\exp(j.\gamma_{i,j})\right\}$$

with n(t) as AWGN with two-sided PSD No/2.

Now channel output includes total of (2L-1) paths with a strong peak with (j+l = L-1). Hence only one rake finger is needed in the mobile unit to synchronize this path. This makes an easier design for portable handsets. Output of the finger employed in the receiver of user number 1 is given by

$$Z_1=D+S+A+N$$

with D as desired part for current bit given by k = 1 part of $r_l(t)$, S as self-interference, A as multiple access interference and N as zero mean Gaussian noise with variance equal to No/4. After solving the equations, the desired data will be given by[4]

$$D=\sqrt{\frac{P}{2}}.b_{1,0}.T.\sqrt{U_1}$$

$$S=\frac{P.T_c^2}{2.U_1}(2.N.\chi-\mu)$$

with χ and μ are given by:

$$\chi=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}\beta_{i,j}^2.\beta_{1.m}^2$$

and

$$\mu=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}(m-j).\beta_{i,j}^2.\beta_{1.m}^2$$

Finally multiple access interference term A is given by:

$$A=\sqrt{\frac{P}{2}}.\sum_{k=2}^{K}\sum_{j=0}^{L-2}\sum_{m=0}^{L-1}\beta_{1,m}.\beta_{1,j}.\cos\{\omega T_c(j-m)+\gamma_{k,m}.\gamma_{1,j}\}.$$
$$.\int_0^T\left[b_k\{t-(j-m).T_c\}.a_k\{t-(j-m).T_c\}.a_1(t)\right]dt.$$

Hence resulting signal to noise ratio (SNR) is calculated as:

$$SNR=\frac{1}{\left[\frac{1}{2.\gamma_b}+\frac{2.\chi}{N.U_1^2}-\frac{\mu}{N^2.U_1^2}+(k-1)\frac{(\omega+L-1)}{2.N.L}\right]}$$

Where ω = 0 for orthogonal codes and 1 for random codes. Final probability of error for pre-raking is given by

$$P_e=\frac{1}{2}.erfc\sqrt{\frac{SNR}{2}}$$

Similarly, Pe can be calculated for rake process can be calculated as

$$SNR=\frac{1}{\left[\frac{1}{2.\gamma_b.U_1}+\frac{2.\chi}{N.U_1^2}-\frac{\mu}{N^2.U_1}+(k-1)\frac{(\omega U_1^2+\chi)}{N.U_1^2}\right]}$$

The final probability of error for this technique will be as:

$$P_e=\frac{1}{2}.erfc\sqrt{\frac{SNR}{2}}$$

The simulation techniques used for the performance evaluation includes the Monte-Carlo simulation method [5, 6]

5. RESULTS

Parameters taken for simulation are as follows: Number of chips per bit= 64, number of users = 20, Number of Iterations = 5000.

It is clear from Fig (1) that bit error rate reduces with the increase in SNR for fixed number of users and number of channel paths. As clear form figure, it can be seen that both raking and pre-raking gives almost equal performance as far as orthogonal codes are concerned and P_e decreases very slightly with the increase in SNR. But for random codes, pre-raking outperformed raking as P_e decreases sharply if SNR is increased beyond 10.

Now from Fig (2) is simulated with Pe vs. number of users. Probability of error increases with increase in number of users which is natural as more and more number of users tent to give more interference within the system hence more bit error rate and deteriorating the system at last. However here again it can be seen that random codes are preferred for pre-raking, giving better performance than raking.

Finally, from Fig(3) it is observed that as number of paths increases, the performance degrades since more number of paths will tend to introduce more number of interference. It is clear that due to incorporation of diversity P_e starts improving with increase interference from large number of paths of all users but beyond a certain level, it starts increasing hence deterioting the system as whole.

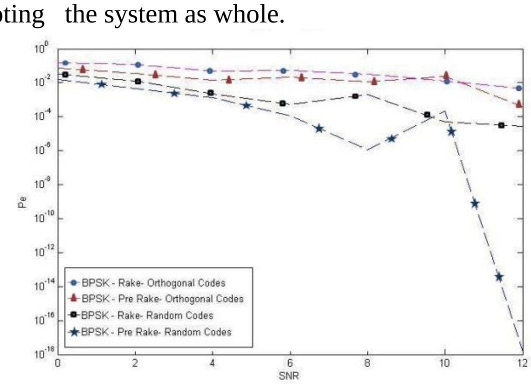

Fig.(1): Prob. of error versus SNR

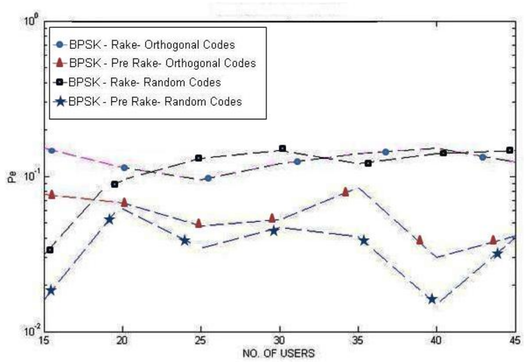

Fig.(2): Prob. of error versus No. of Users

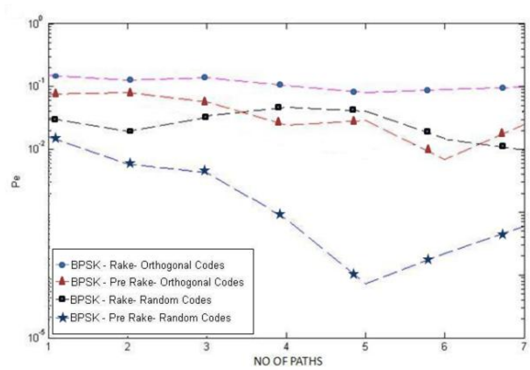

Fig. (3): Prob. of error versus No. of Paths

6. CONCLUSIONS

General overview of CDMA over fading channels had been presented here followed by the concept of rake and Pre-Rake combining techniques are mathematically analyzed. Finally performance analysis (BER) was done analytically for both the schemes and results were discussed. Pre-Rake combining technique has been proposed with TDD CDMA mobile communication. Since the up and down links are on the same carrier, base station can estimate the channel response and pre-rake the signal before transmission to the portable unit. With a simple receiver, employing just one rake finger at the portable unit, the diversity effect is achieved. This greatly reduces the size and cost of the portable unit.

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